Multi-scale studies of the relationships between cropping structure and pest and disease regulation services.

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1 Introduction

Farmers need to regulate numerous pests on each of their crops, using as little pesticide as possible. Several practices can be used to reach this target, yet most of them focus on a single pest. Some control practices implemented for one pest, however, can have antagonistic effects on the development of another pest. Today, with the will to decrease pesticide use while increasing production, studies must take into account the diversity of pests and must focus on tradeoffs in their regulations.

The concept of agroecology proposes to use natural ecological mechanisms in agroecosystems. Plant diversity impacts pest regulation services through biological mechanisms and physical mechanisms. Biological mechanisms typically depend on the species composition of the communities of crop and associated plant. Physical mechanisms typically depend on the spatial structure of crop and associated plant (Schroth *et al.*, 2000). These mechanisms are both supported by empirical research and epidemiological models, yet their relative importance and independent effects are not well known. In the present study, our aim was to assess the relative importance and the independent effects of plant communities' composition and spatial structure on pest communities in tropical and temperate areas. Here we postulate that i) crop composition, sensitive host tissue amount and crop spatial configuration impact pest presence through resource availability and accessibility, ii) associated plant composition and spatial configuration impact pest presence by providing other resources or shelters and through microclimatic variations. The scale necessary to observe such mechanisms would depend on the scale necessary to observe a given level of diversity. In tropical areas, many species can be found in association within small plots, while in simplified temperate agroecosystem a much larger scale would be needed to observe a similar diversity. We first investigate biological and physical effects of biodiversity observationally on tropical agroecosystems in cameroon and second assess through modelling if such mechanisms could be of importance in temperate agroecosystems at a much larger scale.

2 Materials and Methods

In the center region of Cameroon, we did field measures and point pattern analysis in 20 cacao-based agroforest plots (50 x 50 m) to evaluate the impact of plant composition and spatial structure on mirid and black pod regulation, *i.e.* a pest and a disease of cacao (Gidoin *et al.*, 2014). For the temperate region, numerical simulations with population dynamic models were used to study the potential impact of landscape (5000 x 5000 m) composition and configuration on the pollen beetles and phoma stem canker dynamics, *i.e.* a pest and a disease of oilseed rape. Two models were used: i) Mosaïc-Pest (Vinatier *et al.*, 2012) to study the spatio-temporal dynamics of *Meligethes aeneus*, and ii) SIPPOM-WOSR (Lô-Pelzer *et al.*, 2010) to study the spatio-temporal dynamics of stem canker. Finally, we used hierarchical partitioning to quantify the observed or simulated impact of plant structure variables on i) mirid density and black pod prevalence at the plot scale and ii) pollen beetle density and phoma stem canker severity at the landscape scale.

3 Results – Discussion

At the plot scale, in cacao-based agroforests, we found mirid density to linearly increase with sensitive host tissue amount. This relationship explained 18.9 % of mirid density variance independently of the other variables (Fig. 1). On the contrary, host (cacao tree) abundance had a negative relationship with black pod prevalence and explained 20.3% of the variance independently of the other variables (Fig. 1). This was not coherent with the dilution hypothesis (Keesing *et al.*, 2006) as a decrease in host abundance did not correspond to a decrease in disease infection. In addition, the rarely studied horizontal structure of forest trees explained 14.5% of mirid density variance independently of the other variables. Finally, mirid density was lower in plots with aggregated forest trees than in plots with low forest tree density and it was even lower in plots with forest trees distributed randomly. This is coherent with the known aggregation of mirids on cacao trees that are exposed to direct sun light, a situation favored when high forest trees are aggregated (Babin *et al.*, 2010). Interestingly, mirid density and black pod prevalence were impacted by different features of the biodiversity, respectively spatial aggregation of forest trees and host relative abundance. This opens perspectives in reducing mirid density through forest tree spatial structure optimization without increase in black pod prevalence.

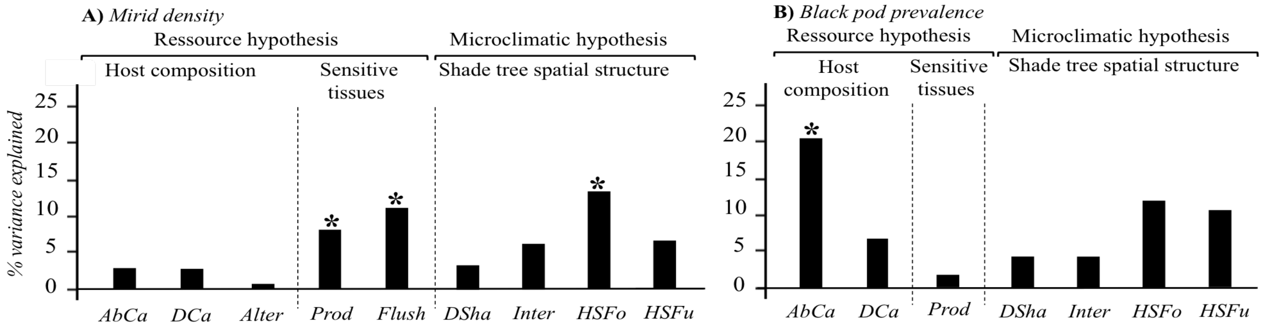

Fig. 1. Results of the hierarchical partitioning analyses: independent contributions of host composition (*AbCa*: cacao tree abundance, *Dca*: cacao tree density, *Alter*: presence/absence of alternative hosts), sensitive host tissues (*Prod*: amount of pods, *Flush*: new leaves presence) and shade tree spatial structure variables (*Dsha*: shade tree density, *Inter*: proportion of shade trees in the intermediate stratum, *HSFo*: horizontal structure of forest trees, *HSFu*: horizontal structure of fruit trees) on A) mirid density and B) black pod prevalence. *Significant contributions (Z-score value).

At the landscape scale, in temperate areas, the first results showed that crop rotation (2 or 10 years, *i.e.* proportion of oilseed rape was about 50% or 10% in the landscape each year) would have a major effect on pollen beetle explaining 86.6% of pollen beetle density variance independently of the other variables tested, *i.e.* trap crop (present or absent) and the forest proportion (less than 3% or more than 25%, which is a wintering site for pollen beetles). This result emphasizes the importance of hosts composition and is consistent with the dilution hypothesis: an increase in rotation length leads to a decrease in oilseed rape proportion and thus a decrease in resource availability for pollen beetles. As changing the crops composition might comes with a very high cost for the farmer, it is important to assess the potential of spatial structure modifications. Aggregation of colza fields has been shown to decrease stem canker severity (Lô-Pelzer *et al.*, 2010). A broader factorial simulation plan is currently designed to test the impact of structural aggregation jointly on pollen beetle density and phoma stem canker severity (with SIPPOM-WOSR).

4 Conclusions

Based on our observations and modelling results, we showed that the dilution of pest resources acts on pest infestation but potentially in opposite directions for black rot on cacao tree in tropical areas and pollen beetles on oil seed rape in temperate areas. Other plant communities' structure variables can affect the pest regulation service and at least in the specific case of black rot and mirid on cacao tree could be used to optimize natural regulations. The impact of plant structures on oil seed rape is still under study but the great diversity of observed relationships between plant diversity and pests natural control suggests that general rules can not be used to guide agronomical practices. In consequence, future research should aim to model the specific characteristics of the main pests of an agrosystem to predict the effect of composition and spatial structures at the relevant scale (Gosme *et al.*, 2013).

References

Babin, R., Hoopen, G.M.T., Cilas, C., Enjalric, F., Yede, Gendre, P. & Lumaret, J.P. (2010). Impact of shade on the spatial distribution of *Sahlbergella singularis* in traditional cocoa agroforests. *Agricultural and forest entomology*, **12**, 69-79.

Gidoin, C., Babin, R., Bagny Beilhe, L., Cilas, C., ten Hoopen, G.M. & Ngo Bieng, M.A. (2014) Tree Spatial Structure, Host Composition and Resource Availability Influence Mirid Density or Black Pod Prevalence in Cacao Agroforests in Cameroon. *PLoS ONE* 9(10): e109405.

Gosme, M., Vinatier, F., Valantin-Morison, M. & Jeuffroy, M.H. (2013). PODYAM: a modeling framework for simulating population dynamics in agricultural mosaics. Presented at the *11th International Epidemiology Workshop*, Beijing, China.

Keesing, F., Holt, R.D. & Ostfeld, R.S. (2006) Effects of species diversity on disease risk. *Ecology letters*, **9**, 485-498.

Lô-Pelzer, E., Bousset, L., Jeuffroy, M.H., Salam, M.U., Pinochet, X., Boillot, M. & Aubertot, J.N. (2010). SIPPOM-WOSR: A simulator for Integrated Pathogen Population Management of phoma stem canker on Winter OilSeed Rape. I. Description of the model. *Field Crops Research*, **118**, 73-81.

Schroth, G., Krauss, U., Gasparotto, L., Aguilar, J.A.D. & Vohland, K. (2000). Pests and diseases in agroforestry systems of the humid tropics. *Agroforestry Systems,* **50**, 199–241.

Vinatier, F., Gosme, M. & Valantin-Morison, M. (2012). A tool for testing integrated pest management strategies on a tritrophic system involving pollen beetle, its parasitoid and oilseed rape at the landscape scale. *Landscape Ecology*, **27**, 1421-1433.

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Jeuffroy, MH., **Valantin-Morison**, M.

Three observations form the basis of this work :

1

Farmers need to regulate numerous pests, however, control practices for one pest can sometimes have an opposite effect on the development of another pest.

Heavy shading may reduce **mirid** attacks but could at the same time increase **black pod rot**.

Nowadays, studies must take into account the whole diversity of pests and focus on tradeoffs in their regulation

Three observations form the basis of this work :

2

Plant diversity impacts pest regulation services through several biological and physical mechanisms

Ratnadass et al., 2012 ; Malezieux et al., 2012

Crop composition effect:
A reduction in host abundance decreases the infestation of pests due to resource dilution

Crop configuration effect:
Regular distance between hosts reduces the spread of pests

Tree composition effect:
Trees create a microclimate that can increase or decrease pest infestation according to their ecological preferences

Tree configuration effect:
The spatial structure of trees impacts the mean and the variance of microclimatic conditions and can therefore impact pest dynamics

The large number of mechanisms linking plant diversity to pest dynamics can help us to optimize tradeoffs in pest regulation

Three observations form the basis of this work :

3

A landscape is a a spatially or temporally heterogeneous area at any scale relevant to the ecological mechanisms or organism under investigation.

Turner and Gardner, 1991

Tropical | **Temperate**

Plot scale

Larger scale

We must adapt the spatial scale of analyses to the scale necessary to observe a given level of heterogeneity in the environment

Three observations form the basis of this work :

Nowadays, in order to decrease pesticide use while increasing production, studies must take into account pest diversity and focus on regulation tradeoffs.

The large number of mechanisms linking plant diversity to pest dynamics can help us to optimize tradeoffs in pest regulation

We must adapt the spatial scale of analyses to the scale necessary to observe a given level of heterogeneity in the environment

The question :

Taking into account the structure of a landscape, can we improve the regualtion tradeoffs between several pests subject to management antagonisms?

Cases studied and methodology

Tropical / small scale — 1/4 ha

Temperate / large scale — 400 ha

Hierarchical partitionning

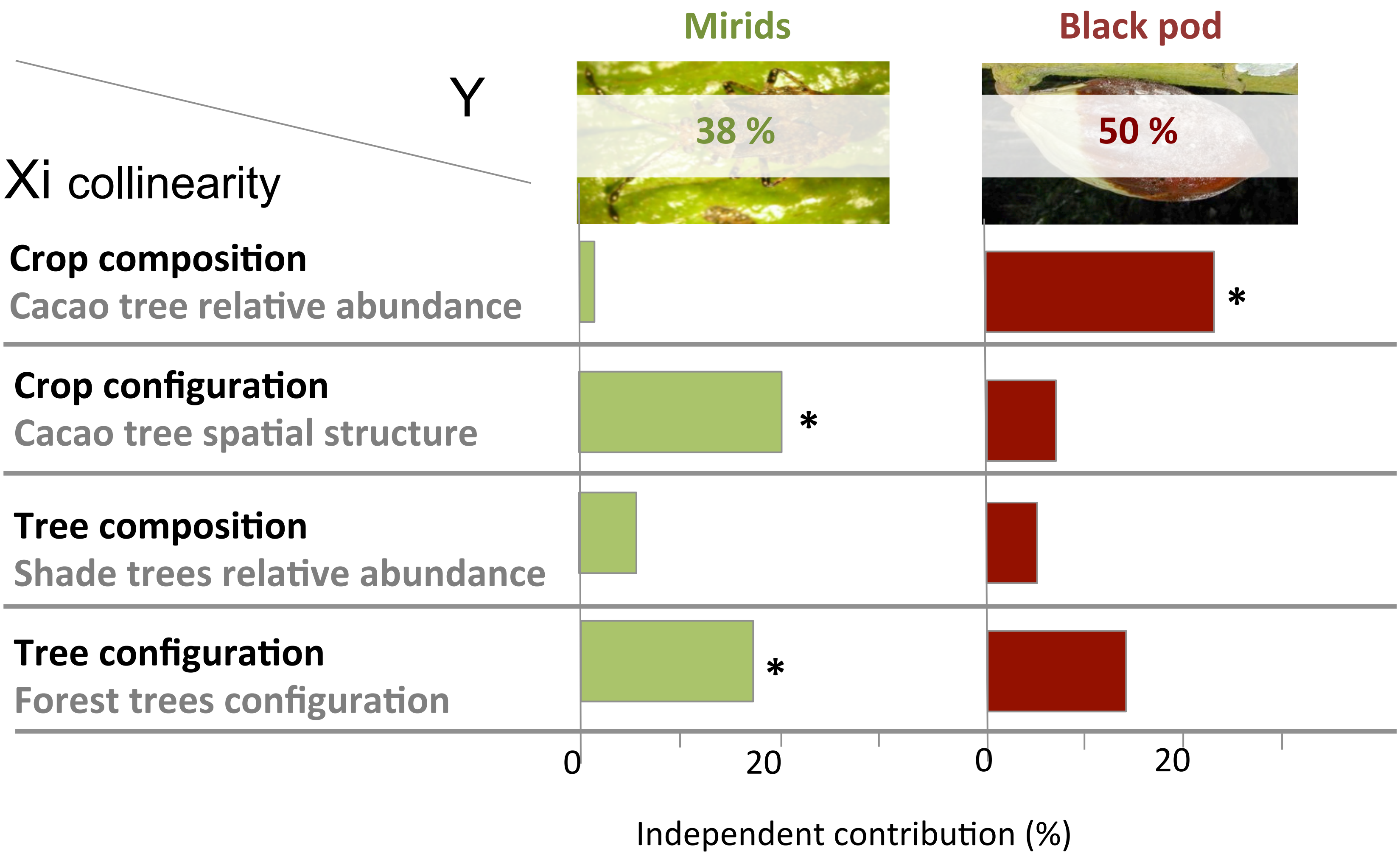




Y / Xi collinearity	Mirids	Black pod	Pollen beetles	Phoma	Parasitoïd
Crop abundance	Low	Low	Low/High	Low	High
Crop configuration	-	Clustered	**Regular**	**Clustered**	**Regular**
Tree abundance	**High**	**Low**	Low	-	-
Tree configuration	Regular	-	Regular	-	-
Methodology	**Empirical data**		**Numerical simulations**		

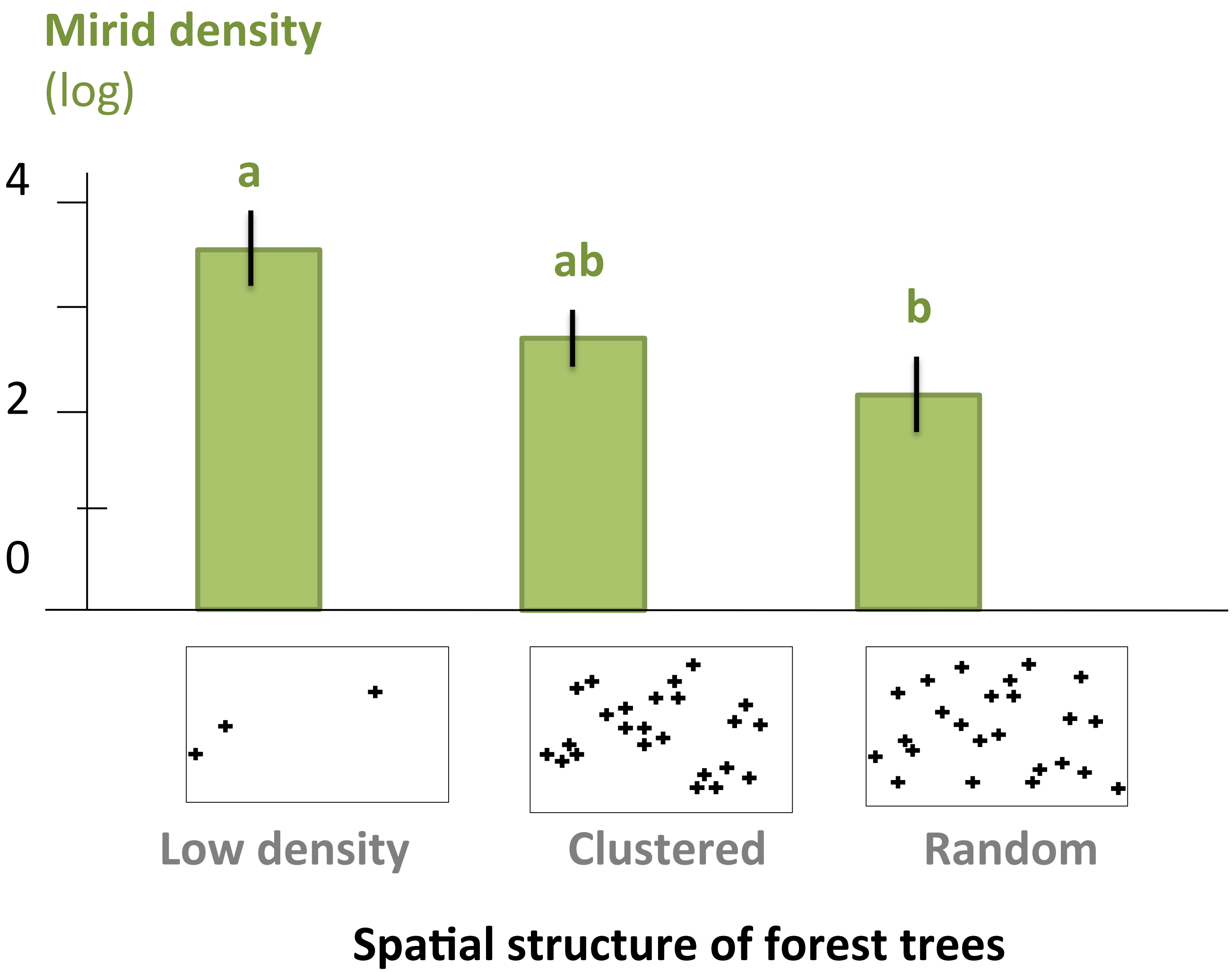
Results and discussion of the tropical study

Hierarchical partitionning



Results and discussion of the tropical study

1- Homogeneous shade reduces mirid density



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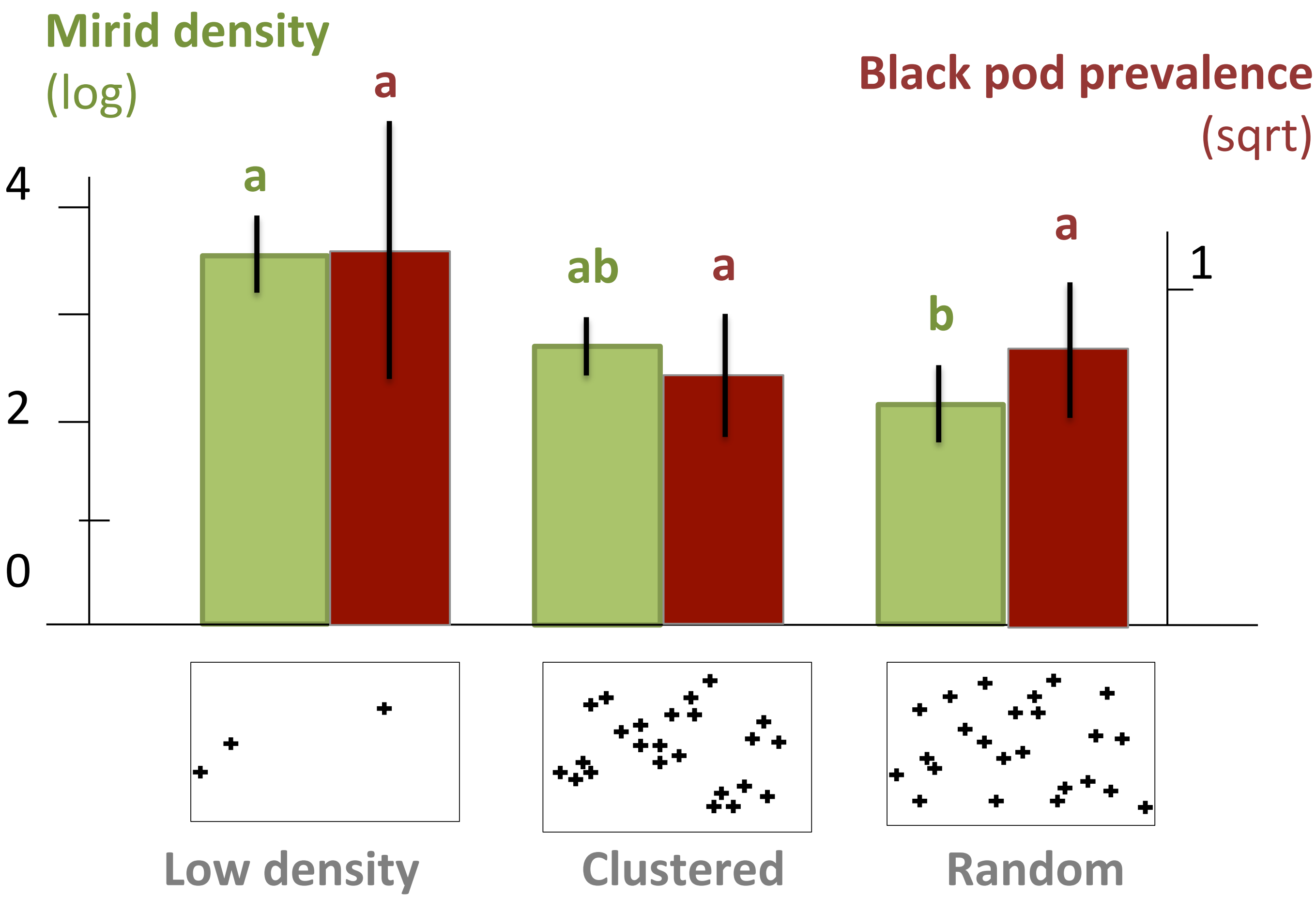
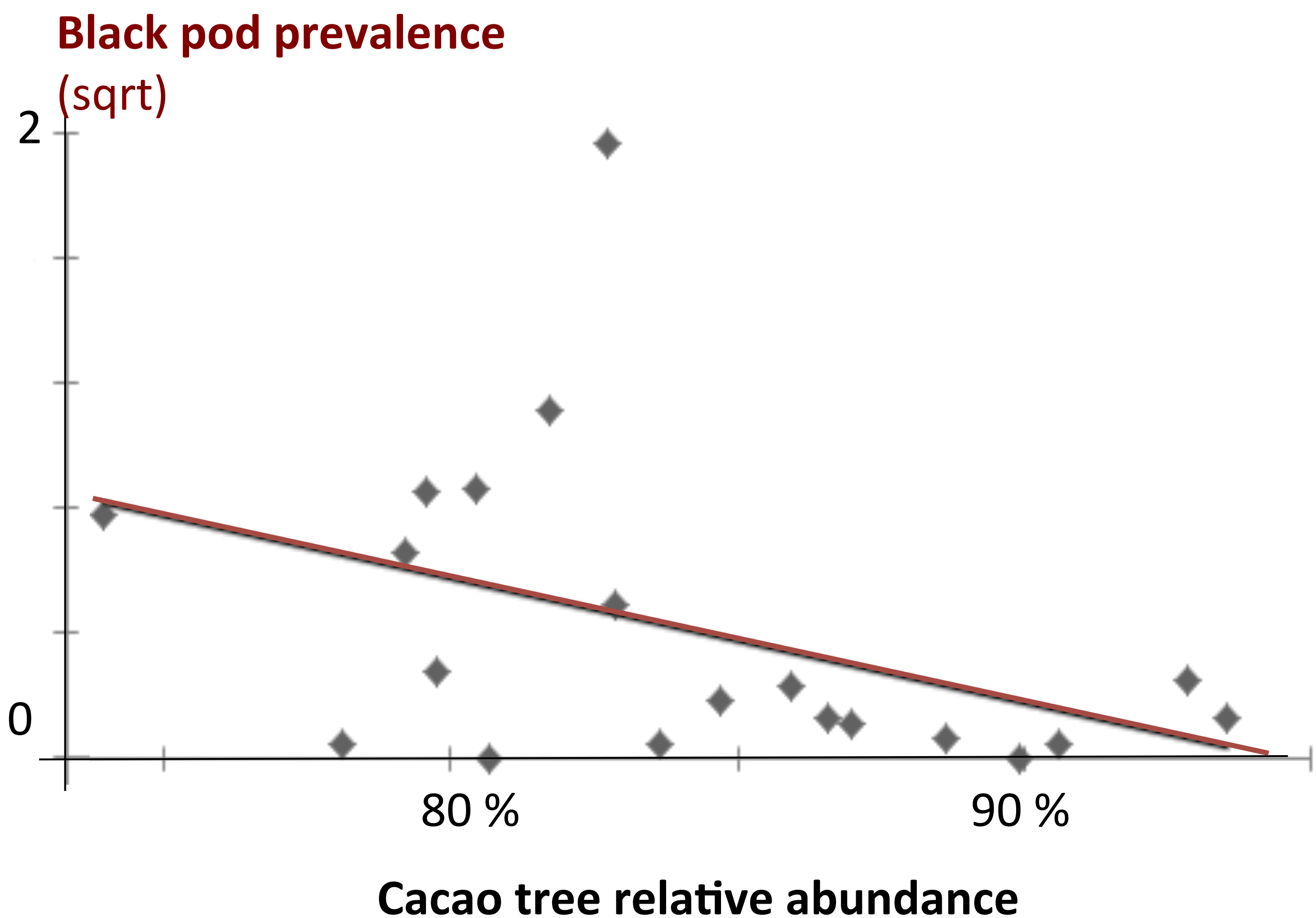


Spatial structure of forest trees

Results and discussion of the tropical study

2- High cacao tree abundance reduces black pod prevalence



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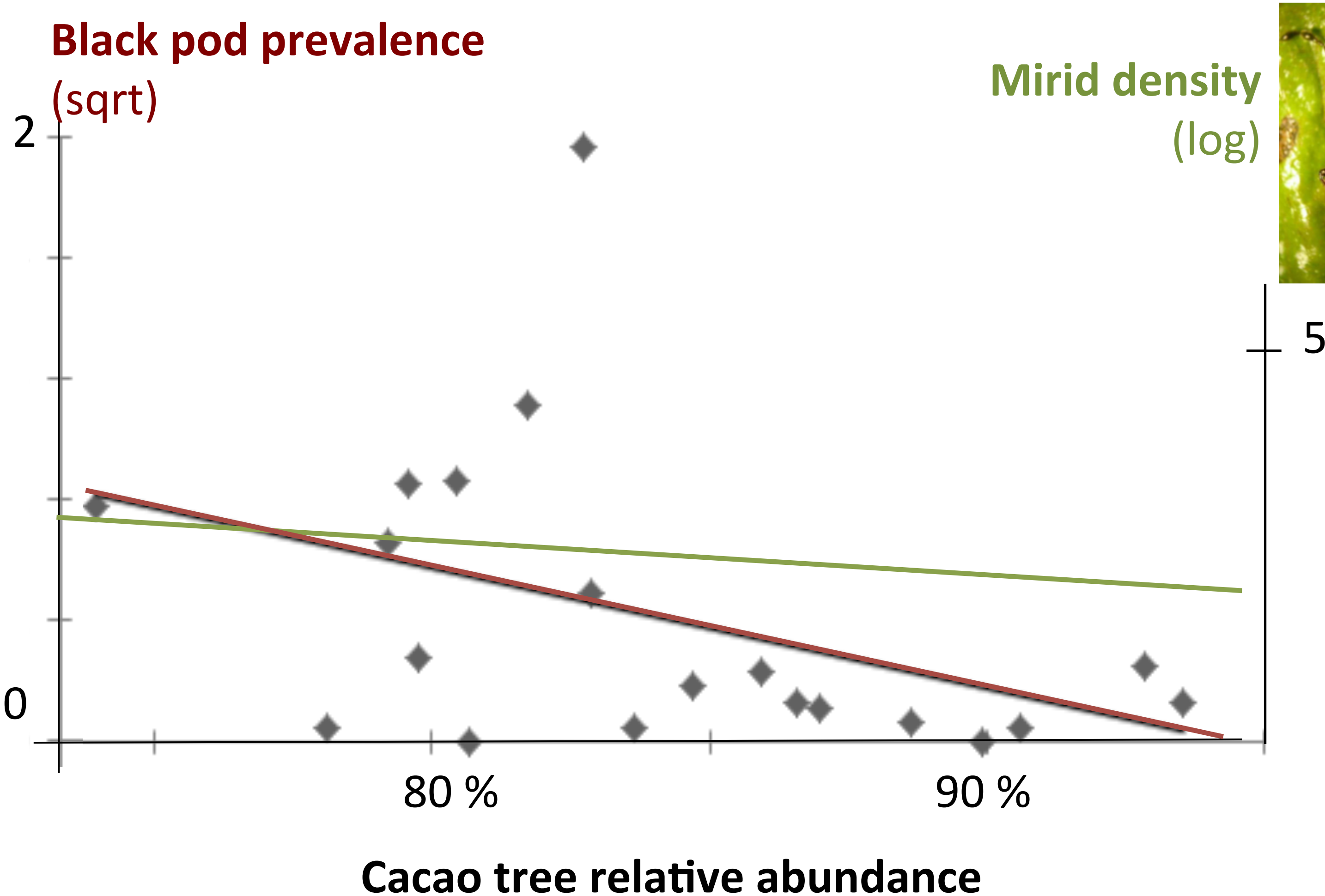
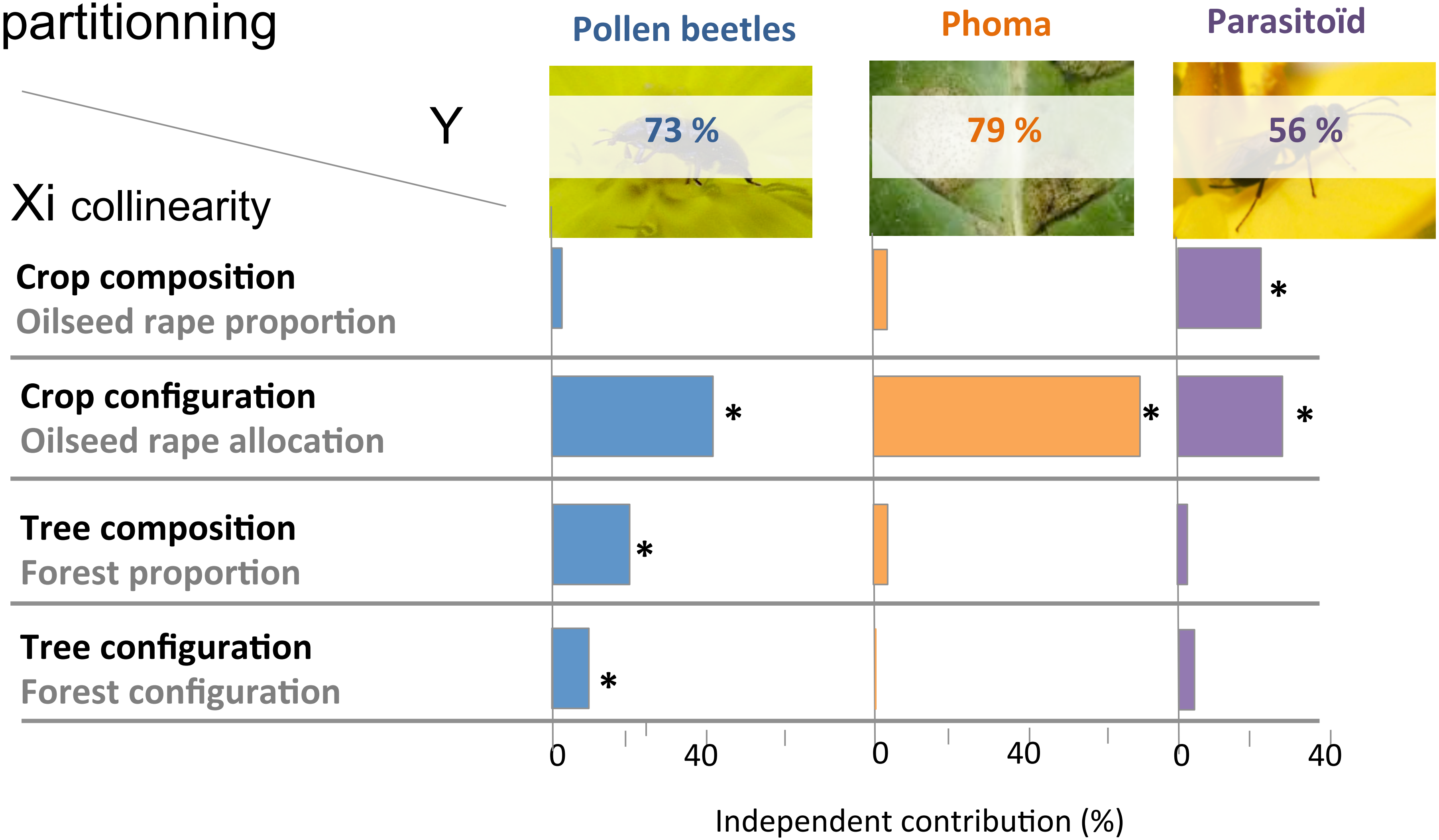


Results and discussion of the temperate study

Hierarchical partitionning

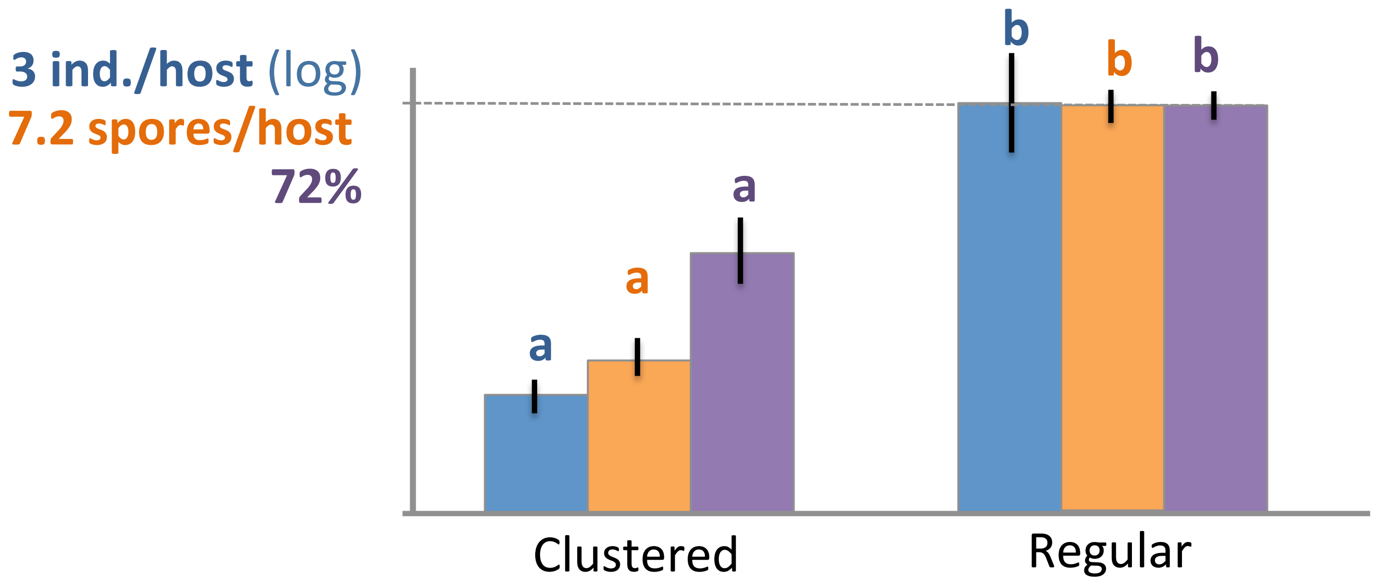


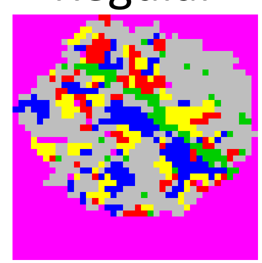
Results and discussion of the temperate study

Pollen beetles

Phoma

Parasitoïd





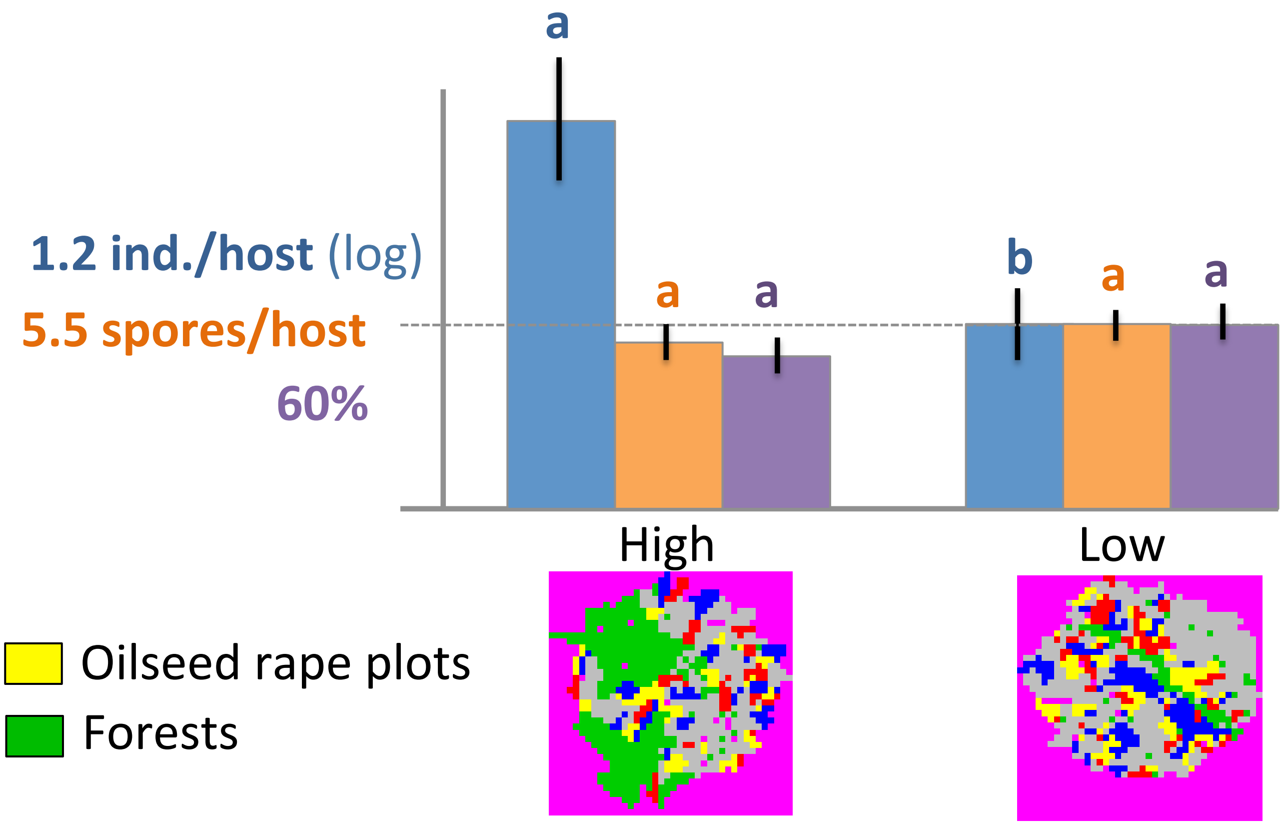
Oilseed rape plots

Forests

Crop configuration : Oilseed rape allocation

Results and discussion of the temperate study

Pollen beetles | **Phoma** | **Parasitoïd**

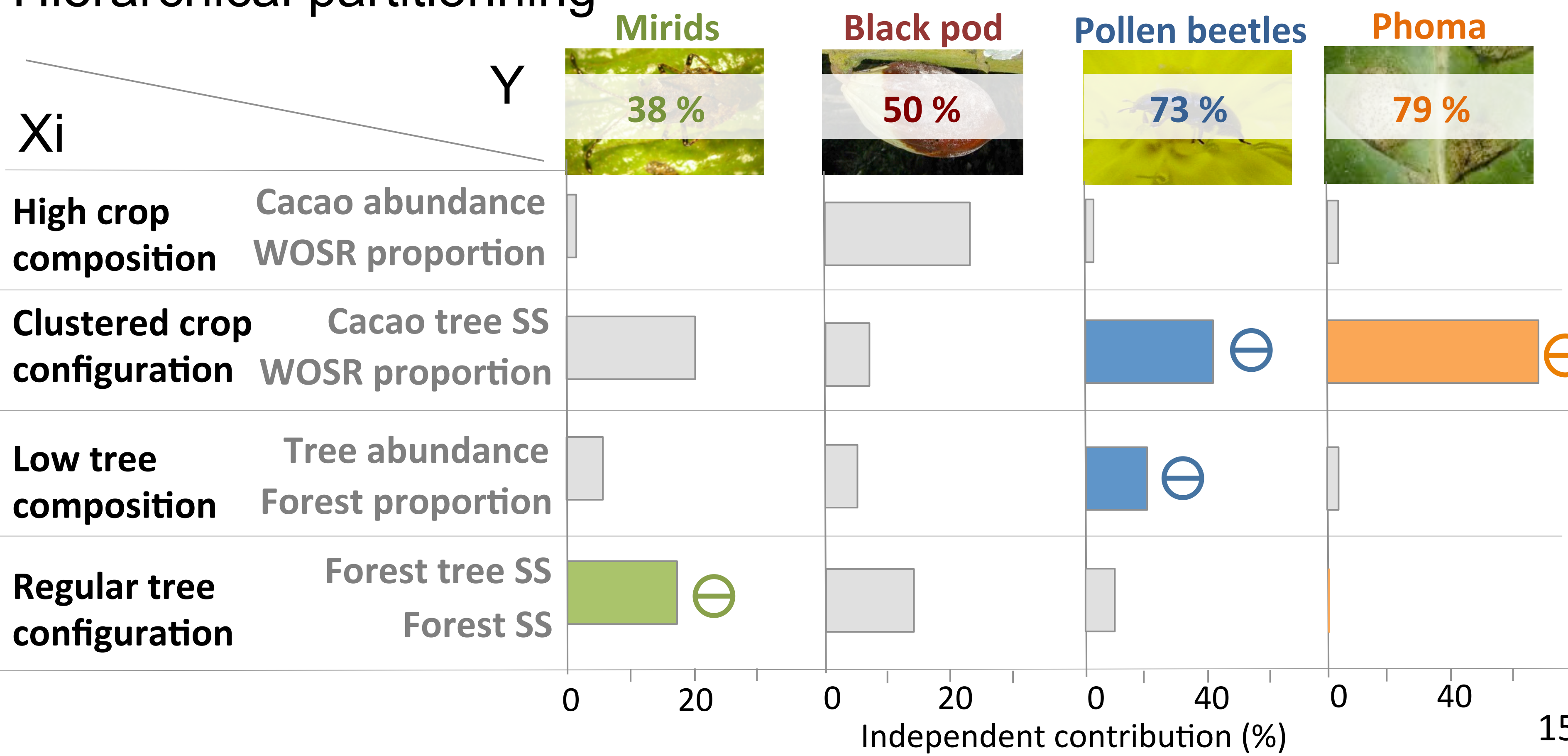


Forest proportion

General discussion and conclusion

- The optimization of landscape structure can improve the tradeoff
- The great diversity of mechanisms suggests that general rules can not be used.
- An analytical framework effective to identify tradeoffs

Hierarchical partitionning



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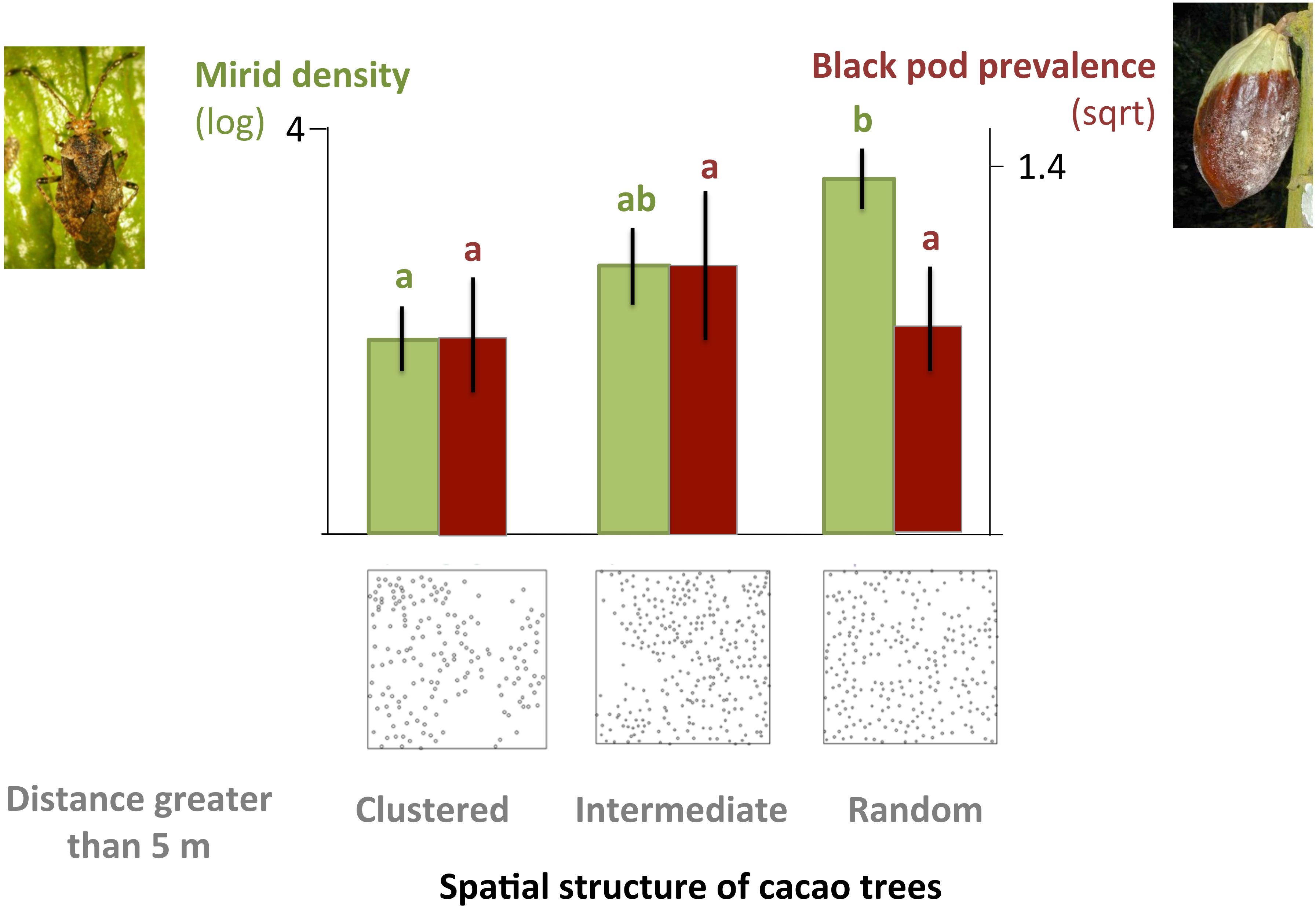
Additional slides

A break in the regular distribution of cocoa reduces mirid density



Hierarchical partitionning